PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvement in Luminous Electric Discharge Tubes

I, HAROLD JOSEPH CHARLES FORRESTER, Chartered Patent Agent, of Jessel Chambers, 88—89—90, Chancery Lane, London, W.C.2, a British Subject, do hereby declare the nature of this invention (which has been communicated to me from abroad by Luminous Tube Lighting Corporation, a corporation duly organized under the laws of the State of Washington, one of the United States of America, of Seattle, County of King, State of Washington, United States of America), and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to luminous electric discharge tubes of the type generally referred to as "spectral discharge" or "ionic discharge" tubes. By this invention, a luminous electric discharge tube and a system of operation therefor in which electrical energy is supplied to the luminous gases by means of a large area conductor separated from the gas by a wall of dielectric material, are provided. By the use of such an electrode, any gas which is stable under the action of an electrical discharge may be used as the illuminant, including the so-called "active gases", because there is no contact between the gases and the conductor. Preferably the gas which is used may be entirely or in part carbon dioxide, since such a gas, when ionized, gives a light approximating daylight, but it is to be understood that any other stable gas may be used.

It has been found that, in order to pass through the gas in the tube sufficient current to give a steady and brilliant light, the electrode area must be very large as compared with the cross-sectional area of the luminous tube if a source of supply with the ordinary commercial frequencies is to be used.

It has also been known for a long time that it is highly desirable to have a large area on an electrode for a luminous tube where the electrodes are to serve as condensers for the passage of current to illuminate the gas on the inside of the tube. It is well known that the capacity of a condenser depends directly upon its area and inversely upon the thickness of its dielectric. There is, however, a limit to how thin the glass of an electrode can be made because of mechanical reasons, and therefore a glass less than a certain minimum thickness is precluded from use, with the result that where high capacity for the condenser is needed, the area must be increased.

Electrostatic capacity electrodes for luminous electric discharge tubes as they have been suggested in the prior art, have been termed "conducting caps" with the caps covering as much as 40% of the tube length in extreme cases. Using the same terminology to refer to the tube lighting system herein disclosed, the "conducting caps" would have to cover approximately 90% of the length of the tube in order to obtain a steady and brilliant light, such as is desirable, and obviously such a length of tube devoted to the electrode would be undesirable.

It has, however, been proposed in British Patent Specification No. 12582/02 to provide a non-conducting tube containing gas or vapour adapted to be rendered luminous by the application of electric energy or current to the terminal of said tube, each end of the luminous tube having attached thereto two or more branches each provided with a conducting envelope or cap.

According to the present invention there is provided a luminous electric discharge tube with external electrodes in which a substantial number of tubes each of smaller diameter than the luminous tube are provided in each electrode and in communication with the luminous tube.

By thus providing a substantial number of tubes of smaller diameter than the luminous tube, the result is attained that the required large surface area is obtained without the disadvantage that was hitherto entailed, that is, that the electrodes were bulky and cumbersome and took up more room than is normally available in lighting constructions.

Furthermore according to this invention there is provided a luminous electric

discharge tube with external electrodes in which a substantial number of closely arranged but spaced tubes each of smaller diameter than the luminous tube are provided in each electrode, these electrode tubes being arranged in groups or rows and being in communication with the luminous tube.

Moreover it is a further feature of this invention that the electrode tubes may be closely spaced and can be arranged in rows so that air can circulate freely and keep the same cool sufficiently to avoid danger of rupture of the glass or dielectric.

It has also been found that in such a tube with such large electrodes, the use of the ordinary transformer by which the voltage of a current supply of commercial frequencies is stepped up to the necessary potential is highly undesirable, if not impossible, because of the resulting unsteadiness or flickering of the light and because of surges in the circuit which may result in puncturing of the tube and destruction of the insulation on the transformer. These difficulties in the arrangement described are caused by the electromotive force applied to the tube being out of phase with the current therein, and according to another feature of our invention this is overcome by associating inductance with the external circuit, preferably in an amount sufficient to cause the current through the tube and the electromotive force to be substantially in phase. In this way, the effect of the large electrostatic capacity, due to the large area electrodes, is substantially neutralized.

While the necessary inductance may be provided independently of the transformer, the transformer itself may conveniently be used for this purpose. In order to accomplish this, a transformer having the proper amount of magnetic leakage can be used.

Good results may be obtained when the current in the tube and the electromotive force are not exactly in phase, but, in such case, it is desirable to protect the windings of the transformer against puncturing which has been found to occur, under such circumstances, in the outside windings of the secondary of the transformer. To prevent such puncturing, a transformer is preferably provided in which these outside windings are more heavily insulated than the remainder of the windings.

Preferably the large surface area electrode is obtained by means of a plurality of small diameter tubes, each connected to the luminous tube, so that the interior of each small tube will be in communication with the interior of the luminous tube. By using small diameter tubes for the electrode portion, the walls therefor can be made thinner than the walls of the luminous tube, with a corresponding increase in the electrostatic capacity. Furthermore, by associating these small tubes in parallel groups or rows, each tube may be supported by the adjacent tubes by providing a material to bridge over the spaces therebetween. The net result of the preferred arrangement is a compact group of small tubes, each of which, while thin and fragile and connected at one end only to the luminous tube, may nevertheless be supported in such a manner that a considerable strength to resist breakage is provided.

Also in carrying out the invention, the electrode may comprise a large number of small electrode tubes that are connected to headers which are in turn connected to another header for connection to the luminous portion of the tube. In this way condenser or dielectric electrodes are made up of sufficient capacitance to provide the desired illumination without requiring an undue amount of space.

There is no contact between the gas that is used inside the tube and conducting material that is applied to the outside of the electrodes at the terminals of the tube. Carbon dioxide or carbon monoxide is preferably used and may be mixed with one or more gases or vapors to provide spectra of the desired sort or to increase the efficiency.

Also a luminous discharge tube or lamp may be provided by this invention of such a character that the desired initial quality, quantity and efficiency of light produced will remain practically unchanged over long periods of operation of the tube and a gaseous discharge tube or lamp may be provided of such a character that the operating efficiency will be maintained substantially unchanged over a long period of time by keeping substantially constant not only the total pressure of the mixture of gases in the discharge tube, but also their partial pressures.

In order that a luminous gas discharge tube using chemically active gases such as carbon dioxide, carbon monoxide, nitrogen, etc., or using mixtures including one or more of these gases, may have a long life during which the quantity, quality and efficiency of light remain practically unchanged, it is necessary that not only the total pressure but also the partial pressures of the constituent gases remain unchanged. While it has been known for many years that carbon dioxide or monoxide will give a fine white light, similar to north sky light, due to a very densely filled and well balanced spectrum, I have found that in order to produce this

light over long periods of time, it is necessary to maintain the equilibrium of the mixture of carbon dioxide, carbon monoxide, oxygen and various sub-oxides of carbon into which carbon dioxide or monoxide breaks up when ionized.

In any gas filled discharge tube there is a gradual disappearance of gas which is called " clean up " and it has been found that in this clean up various gases disappear at different rates. It has been found that an excess of oxygen lowers the efficiency of the tube more than any other constituent gas and also in a tube using dielectric or condenser electrodes and carbon dioxide that oxygen cleans up more slowly than other gases. Therefore it is impossible to obtain long life and maintain efficiency of a tube by merely renewing or supplementing the supply of carbon dioxide since, in so doing, the equilibrium of the mixture is gradually changed and the efficiency of the tube is steadily decreased.

It has been found that in the operation of gaseous discharge lamps, using carbon dioxide, carbon monoxide or other active gases, they will ordinarily change rather rapidly in efficiency and quality of the light produced. This invention makes it possible to maintain the initial efficiency and quality of light produced over long periods of time, exceeding a thousand hours.

By this invention means are provided whereby large and bulky lamps may also be conditioned for use in a simplified manner.

According to another feature of this invention an activator, preferably in the form of porous or finely divided material or material whose area is large compared to its volume, may be placed in direct contact with the gas in the luminous electric discharge tube. Such discharge tubes may be easily and quickly reconditioned in accordance with this invention and proper conditioning of large and bulky lamps of this sort can be effected without employing a baking out treatment.

The invention will be best understood from the following description of illustrative embodiments of the invention.

In the drawings:

Figure 1 is a diagrammatic view showing the preferred form of luminous or ionic discharge tube and associated electrical circuit arrangement.

Figure 2 is an enlarged view, partly in side elevation and partly in longitudinal section, of one of the electrodes.

Figure 3 is an enlarged fragmentary transverse section on the line 3—3 of Figure 2.

Figure 4 is an enlarged fragmentary section on the line 4—4 of Figure 2.

Figure 5 is a view part in section and part in elevation of the electrode and showing a further method of operating the electrodes.

Figure 6 is a view of a type of the transformer that may be employed.

Figure 7 is a section on the line 7—7 of Figure 6.

Figure 8 is a purely diagrammatic view illustrating the method of winding for the secondary coils of the transformer.

Figure 9 shows a modified form of electrode.

Figures 10 and 11 are enlarged fragmentary views on the respective lines in Figure 9 showing detailed features of construction.

Figure 12 is a side view of a modification of the invention partly broken away.

Figure 13 is a side view on an enlarged scale of a group of small electrode tubes connected to a header.

Figure 14 is a section on a still larger scale through two of the small electrode tubes.

Fig. 15 is a somewhat diagrammatic view showing another modification of the invention, together with the electrical circuit.

Figures 16 and 17 are slightly enlarged views of one of the electrodes on the corresponding respective lines shown in Figure 15.

Figure 18 is a detail sectional view through two of the electrode tubes on an enlarged scale.

Referring to the drawings in detail, and wherein similar reference characters designate corresponding parts throughout the several views, and referring particularly to the form of invention disclosed in Figures 1 to 8 inclusive, the letter A designates the luminous tube provided at its ends with the electrodes B. The tube A is preferably formed of glass and may be of any desired form and size desired in accordance with the type of illumination desired for the luminous portion of the tube.

The electrodes B are shown connected in circuit with a transformer C of special construction which is for connection with a supply of low frequency, low voltage alternating current, say of sixty cycle such as ordinarily supplied for commercial use.

Referring now to the specific construction of the large area capacity electrode B, which is chosen for purposes of illustration, the same is made of a dielectric material such as glass and in one practical size has an approximate dimension of eighteen inches in length and three inches in diameter. The electrode comprises a

bell cap 5 for connection to an end of the tube A. The lower side of the hollow bell cap 5 is closed by a flat disc 6 to the under side of which is sealed a large number of small tubes 7 having walls much thinner than the walls of the tube A. These small tubes 7 are closed at their lower ends and have their upper ends in communication with the interior of the hollow bell cap 5 through apertures 8 formed through the disc 6. These thin walled tubes 7 are of equal length and formed of a suitable dielectric material such as glass. By way of example, there may be about one hundred and fifty of these thin walled tubes 7 of about 3 mm. diameter connected in slightly spaced-apart relation to each other. This compact "bundling" of the small tubes 7 provides a very large area electrode as to external surface area compared with the volume of the electrode as a whole.

While various forms of the so-called active gases may be employed, it is preferred to use carbon dioxide for certain purposes, but it is to be distinctly understood that any gases which are stable under the action of electrical discharge may be employed. As will be observed, the interiors of the electrode tubes 7 are in communication with the interior of the tube A and that the electrode tubes form terminals of the container for the gas to be ionized.

In the specific form illustrated, the plurality of small electrode tubes 7 are sealed within a capsule-like container or casing 10, preferably formed of a non-conducting material, such as glass, and, in the example shown, it is of tubular formation and is closed at its lower end. This casing 10 is sealed at its upper end to the hollow bell cap 5 and has an internal diameter slightly greater than the diameter of the group of electrode tubes 7 whereby the outermost annular series of the tubes are spaced slightly from the inner wall of the casing 10. The upper extremity of the casing is provided with an outwardly-pressed annular bead 11 providing an annular internal pocket about the upper extremity of the tubes 7. The lower end of the casing extends slightly below the closed ends of the tubes 7 to provide a small chamber for a purpose to be subsequently explained.

The container or casing 10 may be completely filled with a plastic mass of conducting material 12 forming a conductor for transfer of electrical energy to the gas to be ionized. By way of example, the mass may be agar mixed with salt water, this material being sufficiently "stiff" under the temperatures developed in the electrode to provide desired support for the tubes 7. In the form shown in Fig. 3 this plastic conductor 12 completely fills the casing 10 and entirely encircles each of the small electrode tubes 7. In the form shown in Figure 5, the casing 10 is only partially filled with the plastic conducting material 12 so as to form a support for the lower ends of the small electrode tubes 7, the remaining major portion of the casing being filled with either a luminous or non-luminous gaseous conductor such as ionized neon or a liquid conductor such as water, if so desired. While it is preferred that the casing shall contain a sufficient quantity of the plastic conducting material to form a support for the electrode tubes 7, such material may be omitted and the casing may be filled completely with a gaseous or a liquid conductor.

For the purpose of filling the casing 10 with either a solid, liquid or gaseous conductor, it is provided at its upper end upon the bead 11 with a tip 13 and at its lower end with a tip 14. In the manufacture of the electrode, the tips 13 and 14 are open, permitting the conducting material to be inserted through the tip 13 and the air in the casing to be expelled through the tip 14. After the casing is completely filled with the conducting material, the tip 14 is sealed off and the tip 13 may be also sealed off, as by heating. The tip 14 serves as an entrance opening for a lead-in wire having its end terminating in a coil or a plate of suitable area in the chamber formed below the tubes 7. This terminal conductor or plate 15 is in electrical ocntact with the conducting material 12. The tip 14 may be sealed about the lead-in wire.

The large number of small electrode tubes 7 form in effect a partition of large area between the conducting material 12 and the gas contained in the tube. This constitutes a condenser of considerable capacity, the conducting material 12 and the gas inside the tubes 7 being the plates and the walls of the tubes 7 being the di-electric.

As illustrated in Fig. 1, current is preferably supplied to the luminous tube by means of a transformer, one form of which is illustrated at C. The primary 21 of the transformer is supplied preferably from a commercial source of alternating current 23, which may be a sixty cycle alternating current such as is generally supplied for commercial use. The secondary coils 19 are wound on the core leg 17 of the core 18, one on each side of the primary winding, the wires 20 extending from the respective secondaries to the respective electrodes B.

As already said, if the transformer C

is of the usual type, the light resulting from such an arrangement is unsteady, and this difficulty can be overcome by associating inductance with the circuit.

In the arrangement illustrated, this inductance is provided by variable magnetic shunts produced by a series of soft iron plates 24 between the primary and the secondary windings, these plates being designed to give to the transformer the desired inductance to neutralize, or partially neutralize, the electrical effect of the large capacity electrodes.

In order to minimize the possibility of a potential breakdown in the circuit, the outer turns of each secondary winding are preferably insulated to a greater extent than the remainder of the windings of the secondary, as diagrammatically illustrated in Fig. 8. This greater insulation may be provided by spacing the outer windings a greater distance apart than the inner windings of the coil, by providing a heavier coating of insulation on the wire of these outer windings and by sheets of insulating material, as at 19^1, or by any one or more of these methods.

Referring now to the form of capacity or condenser electrode shown in Figures 9, 10 and 11, the casing 10 shown in Figures 2 and 5 is dispensed with and the grouped series of small electrode tubes 7^1 are connected to and are in communication with a hollow bell cap 5^1 for connection with the ends of the light tube A as in Figure 1. The tubes 7^1 are coated with a metallic material 30, such as aluminium paint, carbon or graphite compositions, to provide a conducting coating upon the entire external surface of the tubes. After the metallic coating is applied, the tubes may be coated with one or more layers of lacquer or other suitable material to provide an insulating coating about and between the tubes to insulate the tubes against brush discharge and resultant production of ozone and consequent waste of energy. This coating of insulation also forms a binder for the tubes as shown in Figure 11 and reduces to a minimum the possibility of a tube being broken. Prior to application of the insulating coating 32, a terminal conductor 35 is electrically connected with the metallic coatings 30 at a point preferably midway the ends of the tubes 7^1. This terminal 35 may consist of strands of wire suitably interwoven between the tubes 7^1 so as to contact with the metallic coating of each tube as shown in Figure 10. This interweaving of the wire 36 serves as a further reinforcement for the relatively small electrode tubes 7^1.

It will be noted that the electrode shown in Figures 9, 10, and 11 does not differ to any great extent from the form shown in Figure 2 aside from the omission of the casing 10 permitting use of liquids, plastic and gaseous forms of conductors in connection with the bundled arrangement of small electrode tubes. In each form of electrode, the basic idea is retained; i.e., the provision of an electrode having a very large external surface area when compared with the overall dimensions of the electrode.

By this arrangement, the capacity of the condenser electrodes is not only increased much beyond the prior art practices, but the electrodes are also changed as to form and adaptability to various commercial uses.

When the electrode capacity is equivalent to that given by 10 to 15 feet of 25 mm. thin-walled glass tubing, electrical surges and flickering in the tube begin to be of importance and, as electrode capacities increase, it becomes essential to change the inductance of the circuit to an extent not heretofore known in the prior art of luminous tubes. When, however, sufficient inductance is provided, a luminous tube of satisfactory brilliance and steadiness is attained. For example, in tests with one of our lamps, with forty feet of light tube, 10 mm. in diameter, with an impressed voltage of 15,000 volts, and with the adjustment of inductance properly made, and each electrode having one hundred feet of 25 mm tubing approximately 350 milliamperes of current flows. Under these conditions, the intensity of illumination emitted by one foot of the light tube, at a distance of one foot, is sixteen foot candles using carbon dioxide as the luminous gas.

As a further illustrative example of the large area electrodes used, reference may be made to satisfactory results obtained by tests on a carbon dioxide luminous tube 34 feet long, a bore of about 7 mm. and a gas pressure of 0.1 mm. When a current of about .245 amperes was applied through such a tube, illumination of about 12 c.p. per foot was obtained. Each of the electrodes used in this example was made up of 168 tubes of thin wall glass known under the Registered Trade Mark Pyrex, each tube being 5 mm. in diameter and about 27 inches long, each electrode having an area of approximately 18000 sq. cm. From this example, the large ratio between the area of our large capacity electrodes as compared with its volume will be evident.

It will be understood that, since nothing is in contact with the gas to be ionized except the glass walls, the tubes have an indefinitely long life.

In Fig. 12, reference character 41 indi

cates the body portion or luminous portion of a luminous electric discharge tube, only the ends thereof near the dielectric electrode terminals being shown. This tube may be made of different lengths, sizes and shapes and may be made of ordinary commercial glass, although it is preferably made of the glass known under the Registered Trade Mark Pyrex or other clear glass that is not easily cracked or broken.

An illustrative embodiment of an electrode at an end of the luminous tube 41 will now be described. A glass header 42 is connected by the connection 43 to an end of the tube 41. A series of spaced headers 44 is connected by connectors 45 to the header 42 on alternate sides thereof in staggered relation, as shown in Figs. 12 and 13. Rows of small electrode tubes 46 are connected to each one of the headers 44. The connections of the tubes and headers may be made by welding and the device may be annealed after assembling to avoid the danger of cracking due to strains in the glass.

The tubes 46 are spaced apart slightly and the groups of tubes 46 which are connected to the headers 44 are preferably located in parallel planes and are preferably installed so that there are vertical air passages between the tubes to facilitate cooling of them by the rising current of air.

A conducting coating 47 (Figure 14) is applied to the outside of each tube 46 over as large a portion thereof as is desired. This coating 47 may also be applied over all or as large a portion as is desired, of the headers 42 and 44 and the connections 43 and 45. Lacquer 48 may be applied to the outside of the coatings 47 to insulate the same and minimize static discharge.

Conductors or lead-in wires 49 may be wound around the glass of the electrodes before the conducting coating 47 is applied and then the lacquer 48 may be applied leaving the ends of the wire 49 exposed for convenience in connecting the coatings of the electrodes to the secondary terminals of the transformer which supplies the power for illumination.

It has been found in operating a dielectric electrode luminous ionic discharge tube of this sort that if the glass at the terminals is heated too much it tends to lose its dielectric properties and if the temperature rises above about 100° C. there is likelihood of the same puncturing and admitting air to the tube. By the present invention the electrode tubes 46 are spaced apart so that the circulation of the air about them keeps the temperature below the danger point. Heat is produced on the inside of the tubes 46 while the tube is in operation. The longer each tube 46 is the more energy dissipated at a given voltage and frequency and the more heat developed in it and the greater likelihood of puncture. The heating effect increases toward the tube ends which are connected to the header 44. The electrode tubes may be run in more than one direction or plane from the header if desired. If desired, a header to which the tubes or tips 46 are sealed may have the end thereof turned at right angles and extend parallel to the tubes 46 and slightly beyond them, thus providing a support upon which the electrode may rest.

Greater condenser areas are obtainable in a given space with smaller diameter tubes, but with smaller cross sectional areas of tubes the heat produced is greater with equal currents. It has been found that a luminous tube which will last many thousands of hours can be made as indicated in the drawings, Figs. 12 to 14, with electrodes made up, for example, of tubes 46 about eight inches long and five mm outside diameter spaced about 2-½ mm when using the ordinary luminous tube transformer of 12000 volt rating, the headers 44 being ten mm outside diameter and spaced about fifteen mm apart with the header 42 of eighteen mm outside diameter and the connection 43 from the header 42 to the luminous tube of twenty mm outside diameter. Palms made up of eight rows of eleven tubes 46 of this size in each row have been found to be adequate. However, the lengths and sizes of the tubes, as well as the number and spacings may be varied over considerable ranges. The thickness of the glass may be varied over considerable ranges, also. When thicker glass is used it permits higher safe temperatures, but less current passes through it with the same dielectric area and same voltage, other conditions being constant. An ordinary luminous tube transformer of 12000 volt rating at 60 cycles will pass 70 milliamperes of current through the electrodes described above, one on each end of 51 ft. 15 mm diameter luminous tubing. Lower voltages cause smaller currents to pass through and higher voltages larger currents. With transformers rated at 2000 to 9000 volts longer tubes 46 may be used and the spaces between the tubes reduced while with higher voltages the tubes 46 may be shortened or the spaces between them increased, or both, in order to maintain safe operating temperatures.

It is to be understood that the electrode conducting coating 47 is not confined to the tubes or tips 46, but that the headers to which these tips are connected may also be coated to form a portion of

the electrode. Surfaces of larger electrodes and larger tips provide larger electrode areas so that more current may be delivered from them to luminous tubes than is possible with smaller headers and tips.

Carbon dioxide or carbon monoxide in the tube gives a light that matches clear north sky light. It is desirable to have the tube emit a light constant in spectrum and for the tube to have a long life. Modifications of the light may be obtained by filling the tube with mixtures of helium and carbon dioxide or other gases. In operation the light emitted by the mixture may appear to the eye to be white, although the spectrum contains increased red, red-orange and orange-yellow compared to the light given off by pure carbon dioxide or carbon monoxide. The luminous efficiency of a helium and carbon dioxide mixture is greater than that of carbon dioxide alone. Mixtures of other suitable gases may be used to obtain different spectra.

It is necessary to remove all mechanical stress due to uneven heating in the assembly of the electrodes by carefully annealing the completed electrode. This is done in order to increase the mechanical strength of the electrode and to insure the even distribution of the electrical stresses which are set up when the tube is operating. This can be done by heating the electrodes slightly above 700° C. in the case of the glass known under the Registered Trade Mark Pyrex, or the softening temperature of any other glass used, while the parts are supported so that they will not sag, and allowing the electrodes to cool slowly.

The conducting coating 47 should remain in close contact with the glass and should not be one that would corrode in use. Different conducting materials may be used for this purpose. Lead, for example, is suitable. The lead, which may contain small amounts of tin, may be applied by dipping the electrodes into a molten bath of lead at a temperature just above its fusing temperature. The lower the melting point of the conducting coating the less danger there is of introducing cooling strains in the glass, and the higher the melting point of the coating the less danger there is of its melting off when the tube is operated.

The lacquer coatings 48 are desirable because at voltages at about 9000 or more static discharges take place without them, forming ozone and causing a noise. It has been found that a few coats of lacquer decrease or obviate static discharges and prevent ozone from being formed and also prevent oxidation of the coating when made of metal.

It is to be understood that the dielectric electrode may be made as described above with the conducting material on the outside or with the conducting material on the inside of the dielectric and the gas on the outside of the dielectric and contained in a capsule or container When conducting material is used on the inside it may be in the form of a plate that is flat or spiral, for example, and coated with the glass known under the Registered Trade Mark Pyrex, porcelain or other dielectric of the required thickness.

In Figs. 15, 16 and 17 of the drawings, the letter A designates the body portion or luminous portion of the gaseous or luminous electric discharge tube, provided at each end with a dielectric electrode B. A transformer C is indicated having electrical connection with the electrodes B. Means D is shown for maintaining the equilibrium of the gaseous mixture in the tube section.

The tube A may be of any suitable material, size or shape in accordance with the particular use for which the lamp is intended and may be made from any clear glass that is not easily cracked or broken.

The electrodes B may be formed of any suitable glass capable of withstanding ordinary strains encountered in apparatus of this character. Each electrode B comprises a main header 55 sealed to the tube A. A series of preferably L-shaped carrier tubes or headers 56, preferably of less diameter than the main header tube 55, is connected in parallel spaced-apart relation along the length of the header 55 to project in right angular relation thereto. A series or group of electrode tubes or tips 57, which may be of less diameter than the header 56 and extend in parallel spaced-apart relation to one another and to the vertical or long leg of the header, is connected to the short or horizontal leg of each header 56. These groups of tubes or tips 57 are arranged in parallel planes whereby vertical air spaces are provided between the tubes.

A coating 58 of conducting material, as shown in Figure 18, is applied over the entire or any suitably large portion of the tubes, and a suitable lacquer 59 may be applied over this material to insulate the same and minimize static discharge.

A terminal wire 60 which is rigidly embedded in the conducting material and lacquer covering is looped about the headers 56 prior to application of the coating 58 to the electrodes. These terminal wires have one end exposed for making connections with the secondary terminals of the transformer C.

The means indicated at D (Fig. 15) con-

sists broadly of a device for effecting contact between a properly conditioned porous material or a finely divided material or substance whose area is large compared to its volume and the gas in the discharge tube, thus preserving not only the total pressure of a mixture of gases in the tube constant, but also their partial pressures.

This is done in the embodiment of the invention shown in Figs. 15—17 by placing finely divided or porous material, as indicated at 70, in a small glass appendix or the like connected to the discharge tube at any suitable point and preferably adjacent one of the electrodes. In the example illustrated, this appendix embodies a bulb-like container portion 71 having a small neck or tube 72 which is connected to the discharge tube. One or any other desired number of these appendixes may be connected to the discharge tube at convenient places, such as the ends or intermediate portions. While the finely divided or porous material 70 is preferably placed in an appendix for connection to the discharge tube, the material may be placed in suitable quantities in either the headers 56 or tips 57 or the tube A, if desired.

The material 70 may be conditioned before it is placed in the appendix in such a way that it will adsorb or absorb large quantities of gas or mixture of gases. The conditioning of the finely divided or porous material may be effected by heating the same to drive off undesirable vapors or gases, leaving the same in a condition to readily adsorb or absorb the desired gas or gases. However, it has been found in some cases that charcoal, for example, can be used without any special conditioning. The desired gas or gases may be adsorbed or absorbed by the finely divided or porous material either before or after it is placed in the appendix or before or after the appendix containing it is attached to a lamp tube, simply by bringing the gas into contact with the material.

In operation of the luminous electric discharge tube shown in Figs. 15—18, there is a constant exchange of molecules between the gaseous and the absorbed or adsorbed phases whereby the gaseous phase will tend towards a mixture corresponding to the average in both phases. Thus, by having the properly conditioned material 70 in contact with the gas in the discharge tube, the proportions of the gaseous mixture in the tube will be maintained substantially constant by the absorbed or adsorbed phase in the appendix. Also, when there are small quantities of water vapor or other impurities in the discharge tube which would affect its efficiency, they will be taken up by the material in the appendix after several minutes of running the tube, and will only slightly dilute the gas absorbed or adsorbed in it.

In a comparison test two lamps or discharge tubes consisting of twenty-three feet of 11 mm tubing with dielectric electrodes similar to those described herein were given identical treatments with the exception that one lamp was provided with an appendix as described herein containing about two or three cubic centimeters of willow charcoal. Each lamp was evacuated and baked for several hours at 300° to 350° C. and was allowed to remain over night filled with an atmosphere of carbon dioxide. The pressure was then reduced to about 0.2 mm and the lamps were sealed off. Current was then applied to the lamps and the lamp without the appendix showed signs of decline in fifteen hours of running and went out at the end of approximately twenty-five hours. The pressure in it had dropped to less than 0.02 mm. The other lamp which was provided with the appendix containing charcoal, ran four hundred hours with no apparent change, and when the pressure in this lamp apparently began to drop the bulb 71 of the appendix was gently heated with a small flame and the lamp ran nine hundred additional hours with no perceptible change in efficiency or in quality of light. This heating of the appendix apparently liberated some of the adsorbed gas in the charcoal and increased the rate of transfer of molecules between phases.

If a lamp has been sealed off at too high a pressure, cooling the appendix with carbon dioxide snow or liquid air will give the lamp its desired characteristics.

By other methods, but similar to those previously stated, of conditioning the material 70, lamps have been produced which continuously carried electric current of thirty milliamperes and over for more than a thousand hours with a change of any observable variable of less than ten per cent.

The activator 70 of finely divided or porous material may be willow charcoal, lamp black, bone black, activated carbon, platinum black, powdered glass, powdered ceramic material, etc. The activator material may also be in the form of needles, flakes, etc. Although the activator may be used inside of the lamp proper, and has been so used, there are many advantages in having such activating material in an appendix such as D connected to the lamp. Among these advantages are that large numbers of the appendixes can be prepared and conditioned at one time and sealed off until required; the appendix is not subjected to

the variations in temperature which the lamp proper undergoes; the inside of the lamp is kept free of any foreign substance likely to impair its efficiency, and lamps can be easily reconditioned by merely changing the appendix.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A luminous electric discharge tube provided with external electrodes in which a substantial number of tubes each of smaller diameter than the luminous tube are provided in each electrode and are in communication with the luminous tube.

2. A luminous electric discharge tube provided with external electrodes in which a substantial number of closely arranged but spaced tubes each of smaller diameter than the luminous tube are provided in each electrode, these electrode tubes being arranged in groups or rows and being in communication with the luminous tube.

3. A luminous electric discharge tube as claimed in claim 1 or 2, wherein the smaller tubes forming the electrode are provided on the outside thereof with a conducting material.

4. A luminous electric discharge tube as claimed in claim 3, in which the conducting material surrounds each of the small tubes and is of such consistency to help the small tubes to support each other.

5. A luminous electric discharge tube as claimed in claim 3 or 4, in which the conducting material on the outside of the small tubes consists of metal having a melting point lower than that of the tube.

6. A luminous electric discharge tube as claimed in any of the preceding claims, in which the small tubes are disposed in a series of rows to form a group substantially rectangular in cross section.

7. A luminous electric discharge tube as claimed in any of the preceding claims, in which the surface area of the small tubes is at least one thousand times as large as the cross sectional area of the luminous tube.

8. A luminous electric discharge tube as claimed in any of the preceding claims, in which each small tube is approximately 20 cm long and 5 mm in external diameter.

9. A luminous electric discharge tube as claimed in any of the preceding claims, in which the gas in the tube consists of a mixture of oxides of carbon and other gases, of which helium may be one of such other gases.

10. A luminous electric discharge tube as claimed in any of the preceding claims, in which the small tubes are connected to headers which are in turn connected to the luminous tube.

11. A luminous electric discharge tube as claimed in any of the preceding claims, in which the interior of the luminous tube is in communication with a material, for example activated carbon, conditioned to absorb or adsorb gas and maintain the equilibrium of the gaseous mixture in the tubes.

12. A luminous electric discharge tube as claimed in claim 10, in which the area of the conditioned material is large as compared to its volume.

13. A luminous electric discharge tube as claimed in claim 10, in which the conditioned material is arranged in an appendix which communicates with the luminous tube.

14. A luminous electric discharge tube as claimed in any of the preceding claims, in which the source of electric current supplies alternating current for the luminous tube and the circuit contains sufficient inductance so that the electromotive force applied to the tube is in phase with the electric current therein.

15. A luminous electric discharge tube as claimed in claim 13, in which the circuit includes a transformer with sufficient leakage to supply the requisite inductance.

16. A method of producing a luminous electric discharge tube according to any of claims 1 to 15, characterized by placing an activator in communication with the interior of the device after the latter has been pumped out, gently heating the activator, filling the device to atmospheric pressure with carbon dioxide and after several hours evacuating the device to the desired pressure, then applying an operating current to the device and maintaining communication between the interior thereof and the activator during normal operation of the device.

17. A method of conditioning a luminous electric discharge tube as claimed in claims 1 to 15, which has been sealed off at too high a pressure, characterized by cooling the material with which the gas is in contact to reduce the gas pressure within the tube.

18. A luminous electric discharge tube substantially as set forth and as illustrated in the accompanying drawings.

Dated this 20th day of July, 1934.

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Birmingham,
Agents for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1935.

FIG. 2.

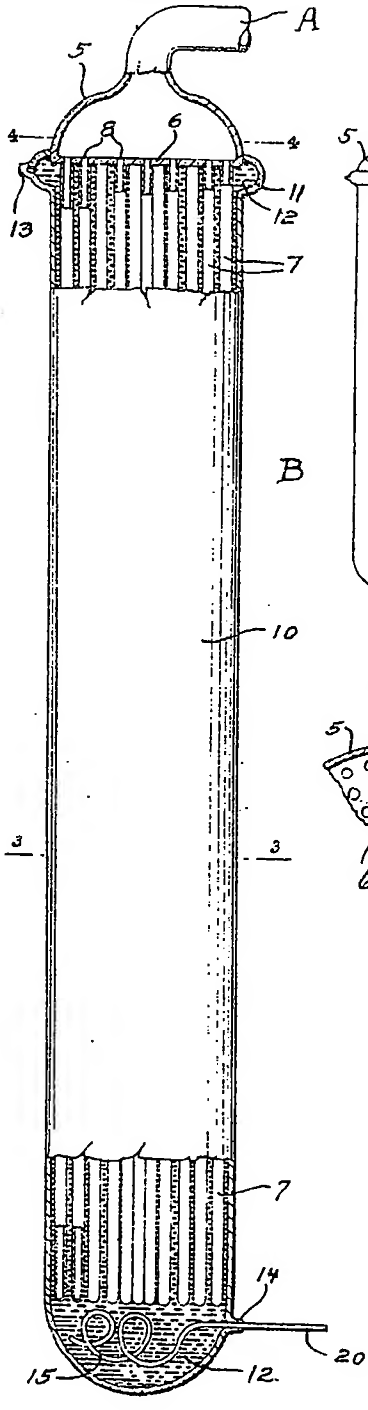
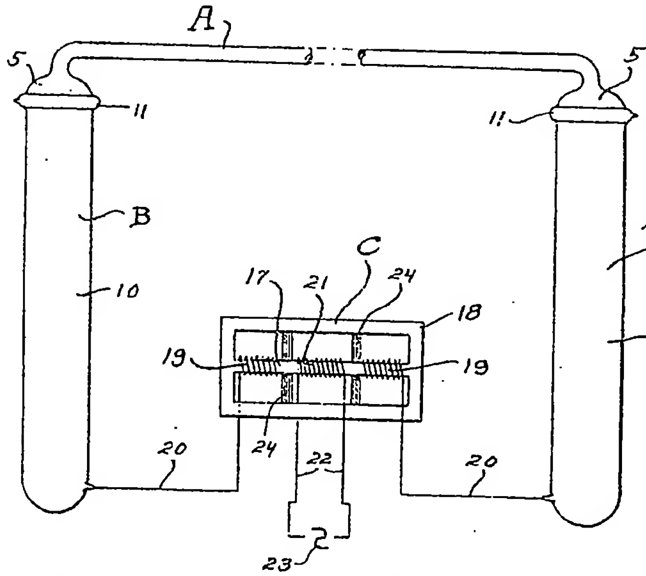


FIG. 1.



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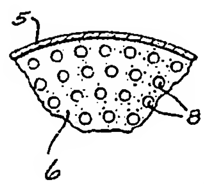

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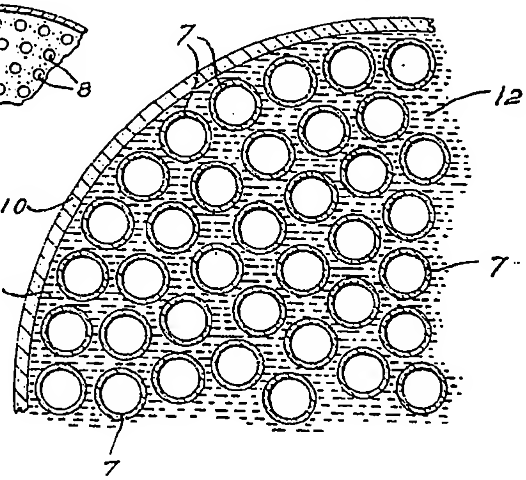

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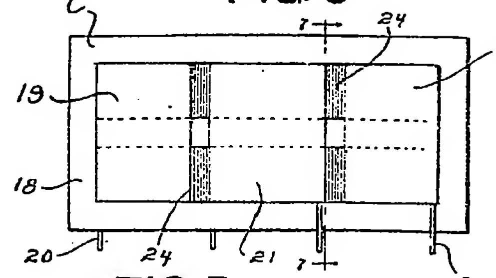
SHEET 1

FIG. 6.



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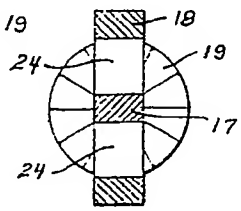

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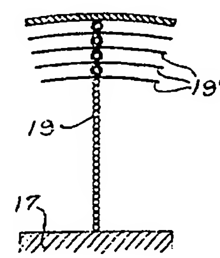

FIG. 5

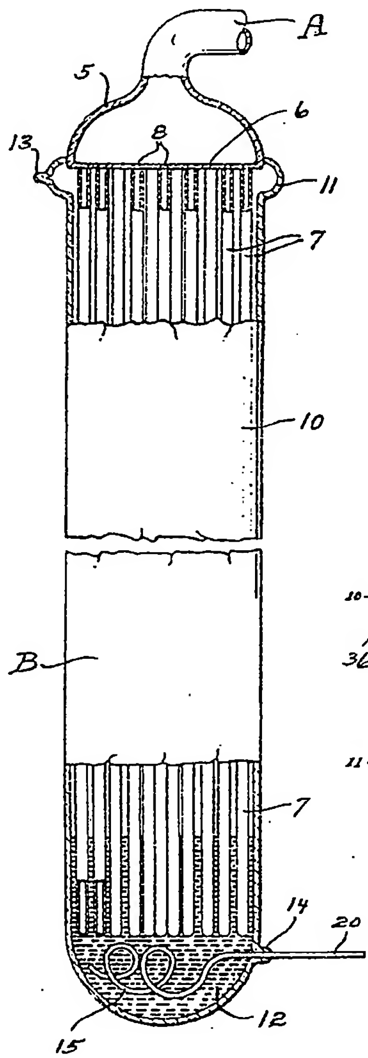

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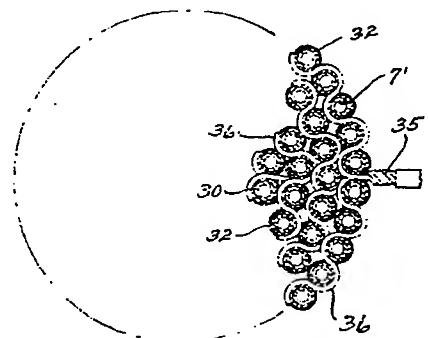
FIG. 10.



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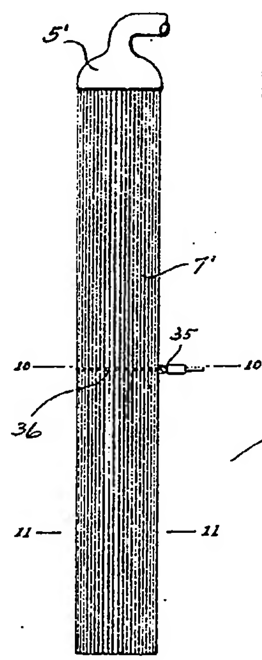

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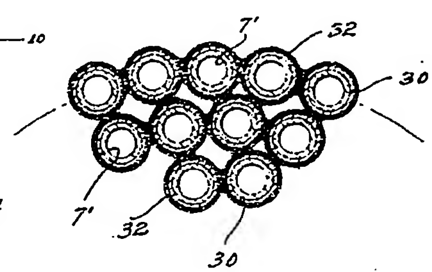

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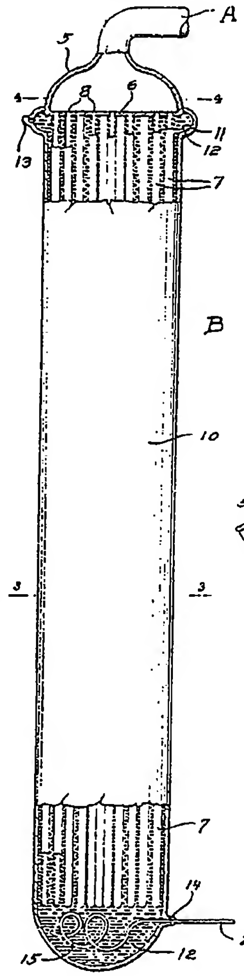
FIG. 2.



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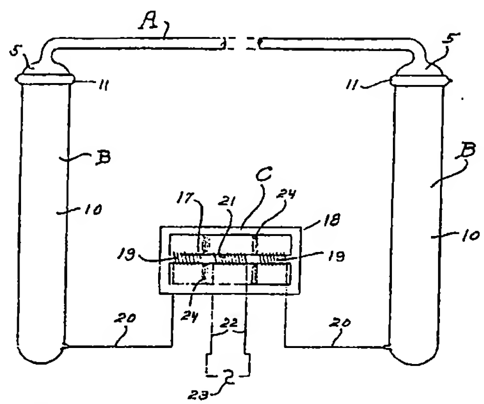

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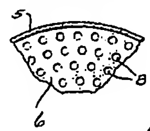

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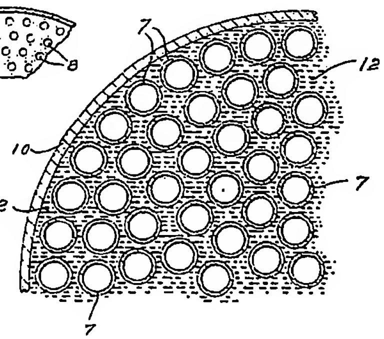

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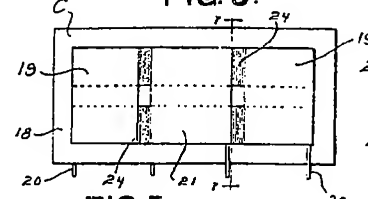

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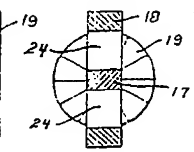

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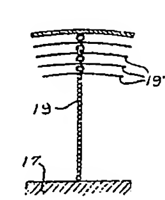

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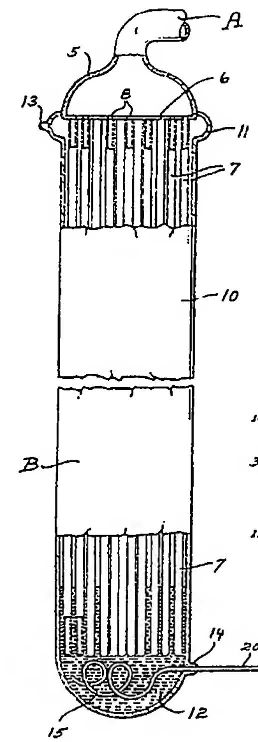

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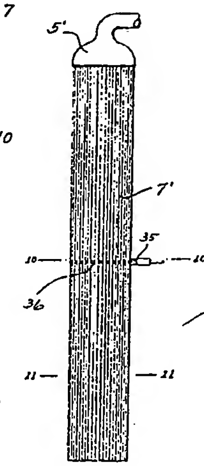

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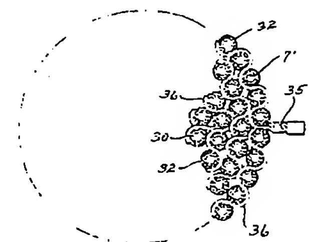

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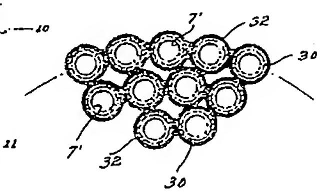

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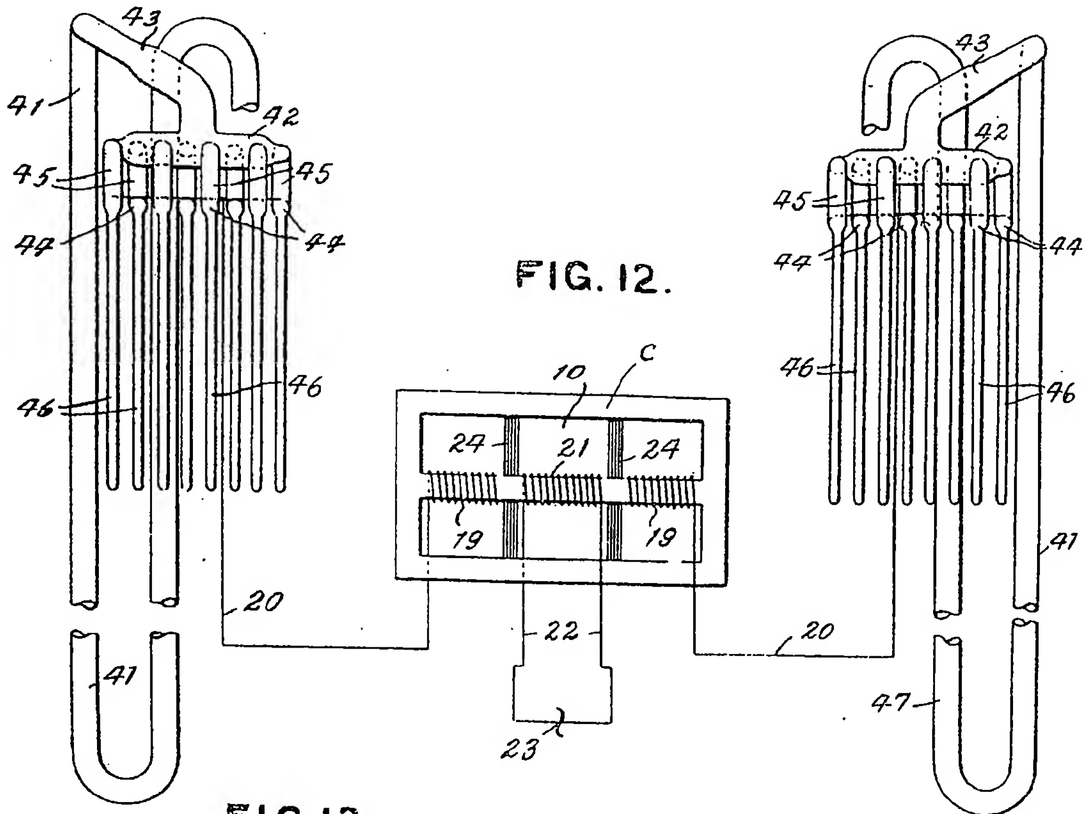

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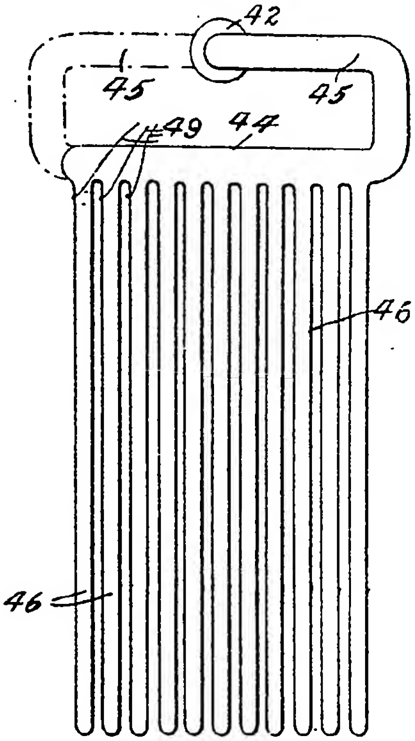

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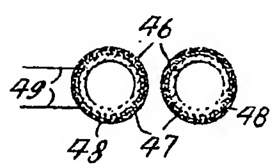
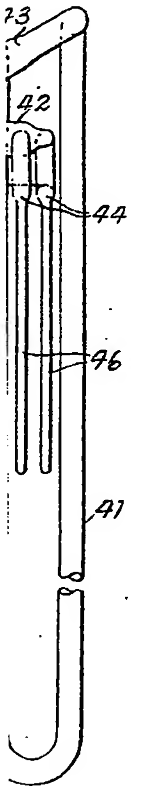


SHEET 3



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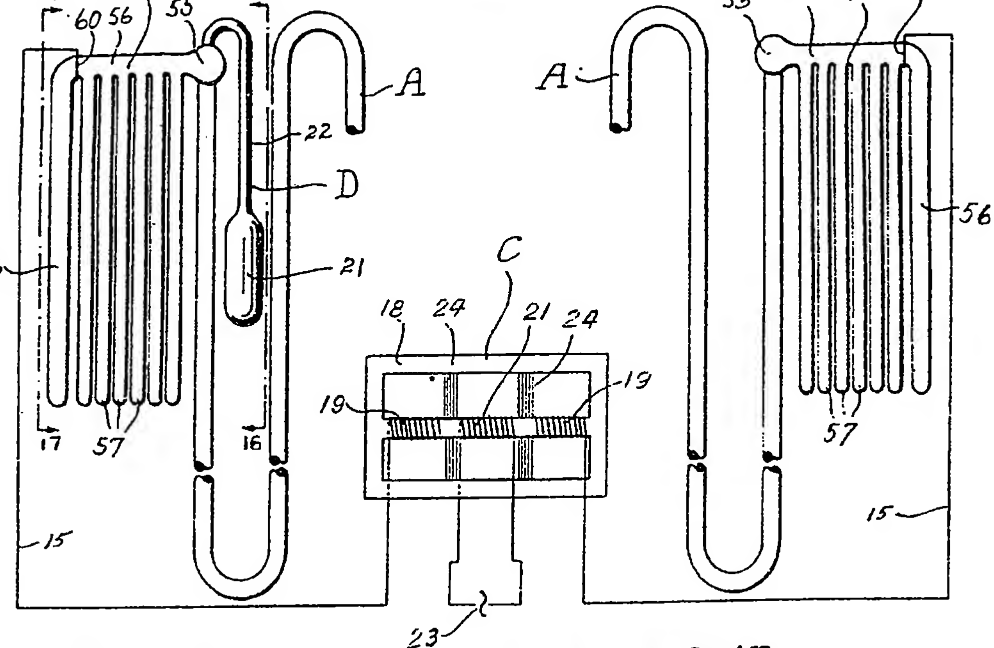

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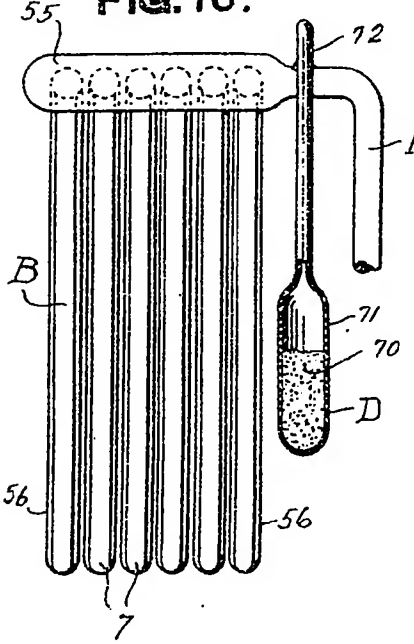

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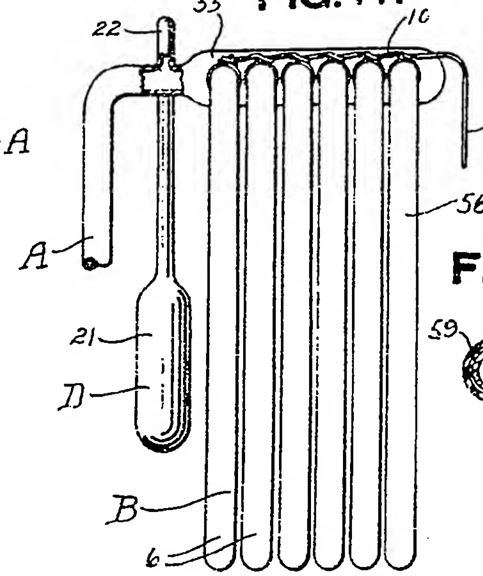

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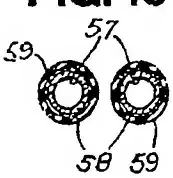

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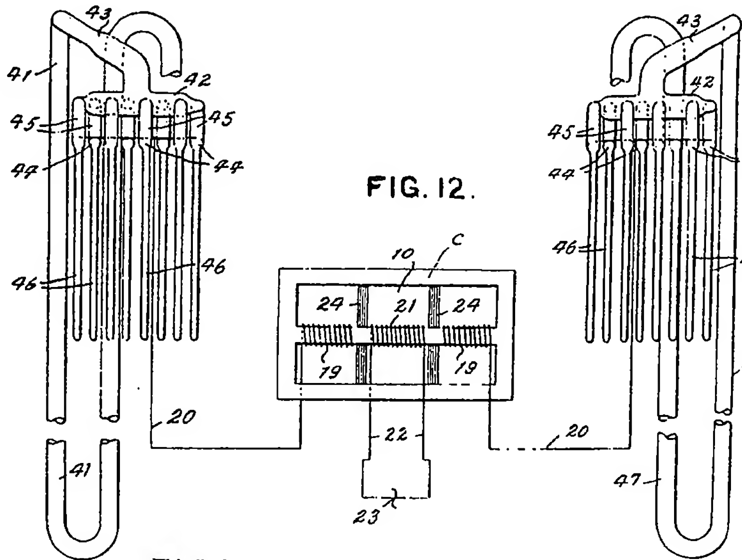

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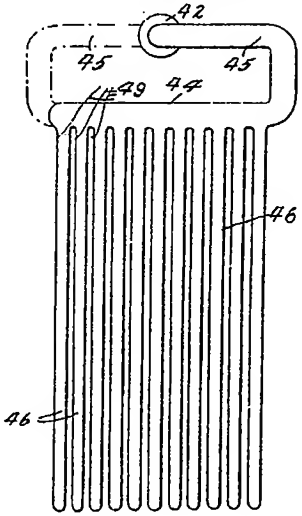

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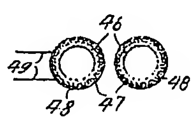

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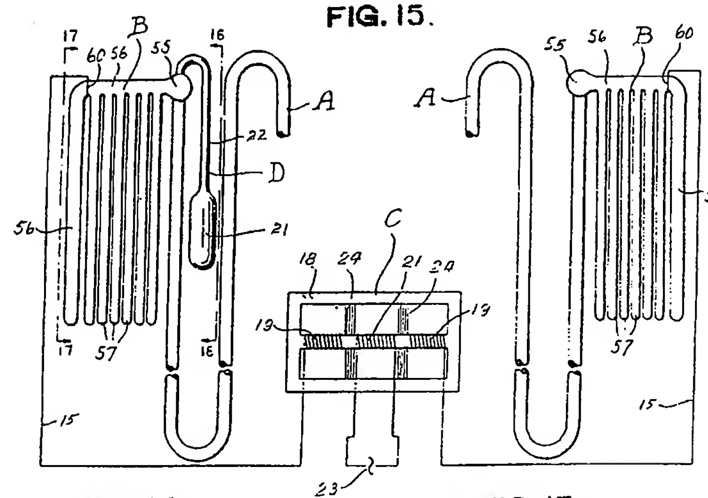

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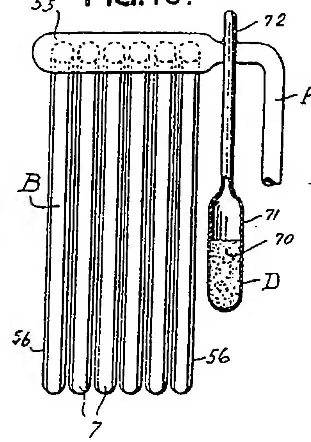

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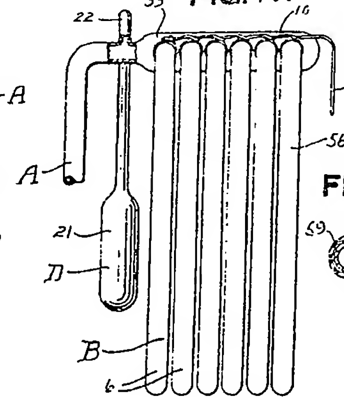

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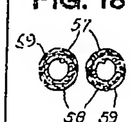

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